

Solicited Proposal for

**Task 4.4**  
**of**  
**“Initial Data Analysis of CRPAQS Field Program Measurements”**  
California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Air Quality Study

Submitted to:

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Program Manager  
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December 14, 2001

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# **1. INTRODUCTION**

## **1.1 Objectives**

This data analysis task intends to understand the temporal and spatial variations of source contributions to particulate matter (PM) concentrations and to determine source zones of influence and receptor zones of representation. Specifically, it evaluates the extent to which CRPAQS captures these variations for annual, seasonal, episodic, and individual periods. This information will add value to the evaluation of the long-term compliance (backbone) network. This will be useful to the Air Resources Board (ARB) and air quality districts as they participate in U.S. EPA's national network evaluation. Source contribution estimates from chemical mass balance (CMB) receptor modeling (from Task 4.1) will be used to conduct this analysis. Results of Task 1.1, 3.1, and 4.1 are needed to complete this task. Answering this question is a natural extension of Task 4.1 "source apportionment" and should be consistent with Task 3.1, which examines temporal and spatial distributions. The results of this task will be needed for comparison with source models and to reconcile emissions with source contribution estimates (Tasks 4.2 and 4.3).

The objectives of Task 4.4 are to:

- Examine the temporal and spatial characteristics of source attributions to PM at the anchor and satellite sites.
- Evaluate the source zones of influence and receptor zones of representation for source contributions at each of the five anchor sites.
- Determine how well long-term compliance (backbone) sites represent source contributions on different spatial scales.

## **1.2 Background**

The California Regional PM<sub>10</sub>/PM<sub>2.5</sub> Air Quality Study (CRPAQS) is a multiyear effort to understand the causes of elevated suspended particulate concentrations and to evaluate ways to reduce them in central California (Watson et al., 1998a). The San Joaquin Valley (SJV) in central California frequently experiences elevated PM<sub>10</sub> (particles with aerodynamic diameters less than 10 µm) concentrations during the fall and winter months. Past studies (Chow et al., 1992b, 1993a, 1996b, 1998) have shown that wintertime particulate matter (PM) concentrations were primarily in the PM<sub>2.5</sub> size fraction (particles with aerodynamic diameters less than 2.5 µm), while during the remainder of the year PM<sub>10</sub> consisted of nearly equal parts of PM<sub>2.5</sub> and coarse particles (PM<sub>10</sub> minus PM<sub>2.5</sub>).

Central California emission source categories include: 1) small- to medium-sized point sources (e.g., power stations, incinerators, cement plants, and steam generators); 2) area sources (e.g., fires, wind-blown dust, petroleum extraction operations, cooking, and residential fuel combustion); 3) mobile sources (e.g., cars, trucks, off-road heavy equipment,

trains, and aircraft); 4) agricultural and ranching activities (e.g., fertilizers, herbicides, tilling, and livestock); and 5) biogenic sources (e.g., oxides of nitrogen from biological activity in soils and hydrocarbon emissions from plants). Agriculture is the main industry in the central valley, with cotton, alfalfa, corn, safflower, grapes, and tomatoes being the major crops. Cattle feedlots, dairies, chickens, and turkeys constitute most of the animal husbandry in the region. Oil and gas production, refining to the south, waste incineration to the northwest, electrical cogeneration at various locations, transportation, commerce, local government, and light manufacturing constitute the remainder of the economy.

Receptor model source apportionments showed that the highest  $PM_{2.5}$  and  $PM_{10}$  concentrations in urban areas during winter contained significant contributions from residential wood combustion, motor vehicle exhaust, and ammonium sulfate  $((NH_4)_2SO_4)$ , with ammonium nitrate  $(NH_4NO_3)$  accounting for 30% to 60% of  $PM_{2.5}$  (Magliano et al., 1998a, 1998b, 1999) and nearly half of  $PM_{10}$  (Chow et al., 1992b).  $(NH_4)_2SO_4$  and  $NH_4NO_3$  were of secondary origin, formed in the atmosphere from direct emissions of gaseous sulfur dioxide ( $SO_2$ ), oxides of nitrogen ( $NO_x$ ), and ammonia ( $NH_3$ ) (Watson et al., 1994b). When contributions from fugitive dust were large, they always resided in the coarse particle fraction.

Magliano et al. (1999) reported temporal and spatial variations in  $PM_{2.5}$  and  $PM_{10}$  source contributions with comparisons to emissions for the 1995 Integrated Monitoring Study (IMS95). Using organic source profiles during IMS95, Schauer and Cass (2000) were able to separate gasoline vs. diesel exhaust, hardwood vs. softwood combustion, meat cooking, and vegetative detritus. Combining gas- and particle-phase organic compounds showed that gasoline-powered vehicle exhaust and gasoline vapors are the largest contributors to non-methane organic gases, followed by natural gas leakage. Primary emissions from residential wood combustion, vehicle exhaust (including both gasoline- and diesel-powered motor vehicle exhaust), and meat cooking contributed ~80% of fine-particle organic compound mass at the Fresno and Bakersfield areas.

This task will examine the results of both conventional CMB apportionment of volatile organic compounds (VOCs),  $PM_{2.5}$  mass, elements, ions, and seven-fraction carbon, and extended-species CMB apportionment of carbonyls, VOCs, semivolatile organic compounds (SVOCs), and speciated particulate organics. Watson et al. (1998b) demonstrated that vehicle contributions from cold start, hot stabilized, high particle emitter, and diesel exhaust could be identified and quantified with organic speciation. The same approach can be used for source apportionment of carbonaceous aerosols,  $SO_2$ , and  $NO_x$ . These species apportionments are useful in reconciling discrepancies between modeling results and emission inventory estimates.

### **1.3 Evaluation Criteria**

The combination of staff, current research projects, facilities, and cost structures of the Desert Research Institute (DRI) will make this proposal especially attractive to the Technical Committee. The evaluation criteria include: 1) technical approach, 2) expertise of the proposed staff, 3) related previous experience, and 4) cost-effectiveness.

The technical approach is presented in Section 3 of this proposal. This approach provides an overview of source apportionment methods to be applied in this task. A summary of CRPAQS ambient measurements applicable to CMB analysis is given along with an update on the current state of the source profile library.

The principals proposed for DRI are unsurpassed in terms of their demonstrated expertise in this type of study. Dr. Judith Chow at DRI has been a major participant in many California air quality studies including:

- *In California's central valley:* the 1988-89 Valley Air Quality Study (VAQS; Chow et al., 1992b, 1993a), 1990 San Joaquin Valley Air Quality Study/Atmospheric Utility Signatures, Predictions, and Experiments (SJVAQS/AUSPEX; Fujita et al., 1995; Chow et al., 1996b), 1995 San Joaquin Valley Integrated Monitoring Study (IMS95; Chow et al., 1998), 1999-2001 CRPAQS aerosol measurements, and 1999-2003 Fresno Supersite Study (Watson et al., 2000; Watson and Chow, 2001a, 2002);
- *Along the Pacific coast of California:* the 1989 Santa Barbara PM<sub>10</sub> Study (Chow et al., 1996a) and 1991-92 Bay Area PM<sub>10</sub> Study (Chow et al., 1995); and
- *In southern and southeastern California:* the 1987 Southern California Air Quality Study (Chow et al., 1994a, 1994b; Fujita et al., 1994; Watson et al., 1994a), 1988 Rubidoux/Riverside Neighborhood-Scale Study (Chow et al., 1992a), and 1992-93 Imperial Valley/Mexicali PM<sub>10</sub> Study (Chow et al., 2000; Chow and Watson, 2001; Watson and Chow, 2001c).

In addition, Dr. Chow applied CMB receptor modeling for the Harvard Six-Cities Health Study (Chow, 1985), State of Nevada Air Pollution Study (Chow et al., 1989), 1987-88 Denver Brown Cloud Study (Watson et al., 1988), 1989-90 Phoenix and Tucson Urban Haze and PM<sub>10</sub> studies (Watson et al., 1991a, 1991b), and 1995-96 Las Vegas Valley PM<sub>10</sub> Study (Chow et al., 1999a). Many of the results from these studies supported the respective states in development of State Implementation Plans. The selected peer-reviewed references attest to her past experience and qualifications.

Dr. Eric Fujita, a Research Professor at DRI, will serve as the co-principal investigator for this task. He has over 20 years of experience in managing and conducting air quality studies such as the 1996-97 Northern Front Range Air Quality Study, 1997 Southern California Ozone Study (SCOS97-NARSTO), and 2000 Central California Ozone Study. Dr. Fujita has extensive experience in source apportionment by receptor modeling. He performed volatile organic compound and PM source apportionment studies for the 1987 Southern California Air Quality Study (SCAQS), 1990 SJVAQS/AUSPEX study, 1993 Coastal Oxidant Assessment for Southeast Texas (COAST), 1995 Boston and Los Angeles Study, 1996-97 Northern Front Range Air Quality Study (NFRAQS), and 1998 Central Texas On-Road Hydrocarbon Study. The tasks conducted here, such as the apportionment of summer intensive samples, will be directly related to the data analysis for SCOS97, in which Dr. Fujita participated.



Dr. Chow and Dr. Fujita will: 1) examine the results of diurnal, temporal, and spatial variations; 2) select episodes for additional testing with spatial contour plots; and 3) conduct sensitivity tests on spatial zones of representation of compliance (backbone) sites. Mr. Matt Gonzi and Mr. Steven Kohl will complete these analyses under the supervision of Drs. Chow and Fujita.

DRI has completed a number of studies (such as the VAQS, Las Vegas PM<sub>10</sub> Study, Imperial Valley/Mexicali cross-border transport study, Mt. Zirkel Visibility Study, and Northern Front Range Air Quality Study) that required the application of different source apportionment techniques. The proposed team demonstrates experience and participation in nearly every one of the major air quality studies conducted over the past two decades. The principal investigator's experience includes major roles in over a dozen major aerosol and visibility source apportionment studies that have resulted in significant advances in the understanding of air pollution. Methods for data analysis are specified in the technical approach in Section 3.

DRI's ability to carry out the proposed work within the time and budget constraints is outlined in Section 5. A key to maintaining the schedule is that DRI staff is well acquainted with the aerosol measurements, emission sources, and CMB receptor modeling in the San Joaquin Valley, and have extensive experience in the analysis and interpretation of source apportionment results.

This project can and will be given priority. The key personnel are fully dedicated to this project. They have been involved in air quality measurements and data analysis in the San Joaquin Valley for more than a decade, and they have always placed this local interest above other more remote opportunities that have presented themselves. DRI is a state agency and is backed by the University and Community College System of Nevada and the State of Nevada. DRI's financial stability as a unit of the University of Nevada System is healthy, long-term, and growing.

With respect to compensation for contracted services, DRI is a non-profit entity and records no financial gain from revenues collected from this or any other project. DRI's interest in this project derives from the unique opportunities it offers to advance our fundamental knowledge about the spatial scales represented by particle samplers. The project has been budgeted to take advantage of different cost structures of the project team. Though DRI must adhere to certain rules established by the Federal Government for cost recovery, it is amenable to alternative arrangements that reduce costs to the sponsors.

Finally, DRI, as part of the State University System, maintains a policy of non-advocacy. DRI participates only in the research aspects of air pollution studies. Results from these studies are presented objectively to decisionmakers without regard to the sensitivities of special interests or political pressures. DRI enjoys the reputation of working equally well with the U.S. EPA, various state and local agencies, and with commercial interests in the development of technical guidance and databases for regulatory analysis.

## 2. SCOPE OF WORK

Task 4.4 of the Request for Proposal includes four sub-questions:

- QUESTION 4.4-1 What is the zone of influence of PM emitters and the zone of representation for PM monitors?
- QUESTION 4.4-2 How does this vary by chemical constituent and by size?
- QUESTION 4.4-3 How well do long-term compliance monitors at backbone sites represent contributions from different spatial scales?
- QUESTION 4.4-4 What are the temporal and spatial variations in source zones of influence and receptor zones of representation?

The following scope of work is structured to answer each of the questions as noted. Each of these subtasks supplies information to address primary **QUESTION 4: WHAT ARE THE SPECIFIC SOURCE CONTRIBUTIONS TO PM<sub>10</sub> AND PM<sub>2.5</sub> CONCENTRATIONS?**

### 2.1 Task 4.4.1 – Determine Diurnal, Temporal, and Spatial Variations in Source Contributions

*addresses:* QUESTION 4.4-2. How does this vary by chemical constituent and by size?  
QUESTION 4.4-4. What are the temporal and spatial variations?

Prepare statistical summaries (averages, maxima, minima, 5th percentiles, and 95th percentiles) of source contribution estimates to PM from CMB modeling results for each site. Compare time-weighted source contribution estimates derived from 5 times/day samples by DRI sequential filter samplers with source contribution estimates derived from collocated samples collected by Airmetrics Minivol samplers. Prepare diurnal plots of source contribution estimates by site for all days and for average of 15 winter episode days. Examine time series plots of PM source attributions during pollution buildup periods and on maximum concentration site-days. Compare primary and secondary source attribution estimates at each site and evaluate differences/similarities among the 8 site types in the satellite network. Prepare spatial pie plots or stacked bar charts of source contribution estimates for annual, seasonal, episodic, and maximum periods.

### 2.2 Task 4.4.2 – Determine Source Zones of Influence and Receptor Zones of Representation

*addresses:* QUESTION 4.4-1. What are the zones of influence and zones of representation?  
QUESTION 4.4-4. What are the temporal and spatial variations?

Calculate spatial and temporal coefficients and averages for each source type and determine zones of influence of different source types using spatial contour plots, geostatistics, and kriging to examine spatial uniformity of primary and secondary aerosol

source contributions. This exercise will provide information on source zones of influence and receptor zones of representation for the five anchor sites (Bethel Island, Sierra Foothill, Fresno, Angiola, and Bakersfield) and one fall intensive site (Corcoran).

### **2.3 Task 4.4.3 – Evaluate Spatial Scales of Influence on Compliance (Backbone) Sites**

*addresses:* QUESTION 4.4-3. How well do long-term compliance monitors represent contributions?

Locate backbone sites that are surrounded with satellite monitors (e.g., Sacramento [S13], Stockton [SOH], San Francisco [SFA], San Jose [SJ4], Modesto [M14], Clovis [CLO], Visalia [VIS], Corcoran [COP], and Mojave [MOJ]). Superimpose backbone sites on a spatial contour map of source contribution estimates for each source type (from Task 4.4.2) and determine source contribution levels from each source type. Compare the sum of source contribution estimates with measured PM<sub>2.5</sub> mass at backbone sites to see whether mass closure can be achieved. Use geostatistics and kriging to estimate source contribution estimates and compare them with estimates obtained from the spatial contour map method. If chemical speciation data are available, conduct CMB with the annual averages, seasonal averages, and selected episode days. Examine changes in spatial contour plots with and without backbone site contribution estimates to further confirm the spatial scales of influence of these long-term monitoring sites.

### 3. TECHNICAL APPROACH

The CRPAQS aerosol monitoring network (Figure 4.4-1) supplements long-term compliance monitoring sites (Figure 4.4-2). The results of the CMB analysis (from Task 4.1) will consist of source contribution estimates for 39 sites in the satellite network and 5 anchor sites as summarized in Tables 4.4-1, 4.4-2, and 4.4-3. These include:

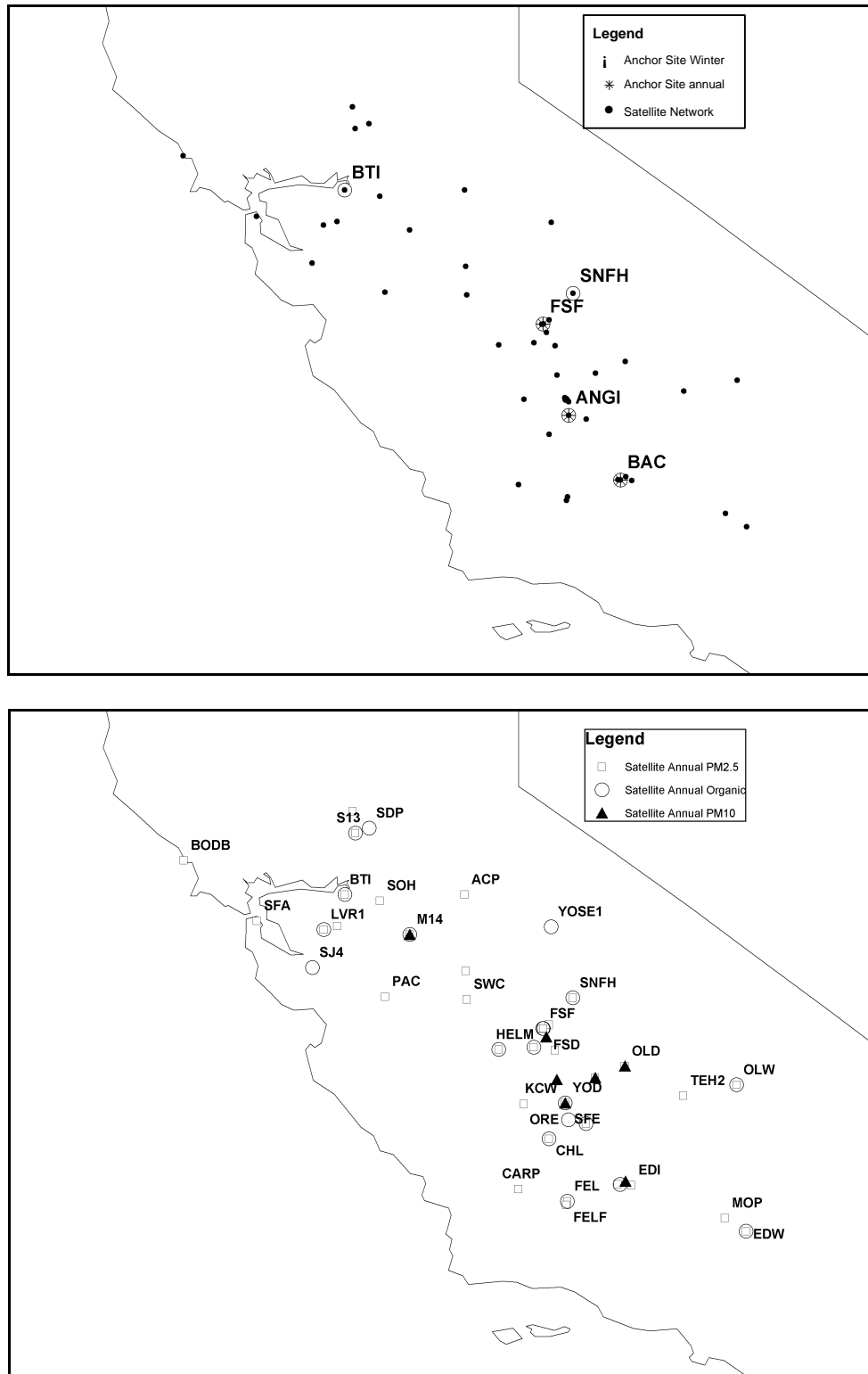
- 5 times/day  $PM_{2.5}$  for winter episodes at Bethel Island, Sierra Foothill, Fresno, Angiola, and Bakersfield.
- 4 times/day VOC ( $C_2$  to  $C_{12}$ ) and carbonyls for winter episodes at Bethel Island, Sierra Foothill, Fresno, and Angiola.
- 2 times/day VOC ( $C_8$  to  $C_{20}$ ) and SVOC and particulate organics at Bethel Island, Sierra Foothill, and Angiola; and 4 times/day VOC ( $C_8$  to  $C_{20}$ ), SVOC, and particulate organics at Fresno.
- 24-hour- and annual-average  $PM_{2.5}$  and  $PM_{10}$  at all satellite sites with full chemistry.
- Annual-average  $PM_{2.5}$  at 20 sites with organics.
- 24-hour-average  $PM_{2.5}$  with organics during summer episode at Fresno.
- 24-hour-average  $PM_{10}$  in Corcoran fall study.
- 24-hour-average  $PM_{2.5}$  at anchor and satellite sites during winter episodes.
- 24-hour-average  $PM_{2.5}$  with organics at Fresno during summer episodes.

Results from the CMB analysis (Task 4.1) will be examined to answer the four questions posed in Task 4.4.

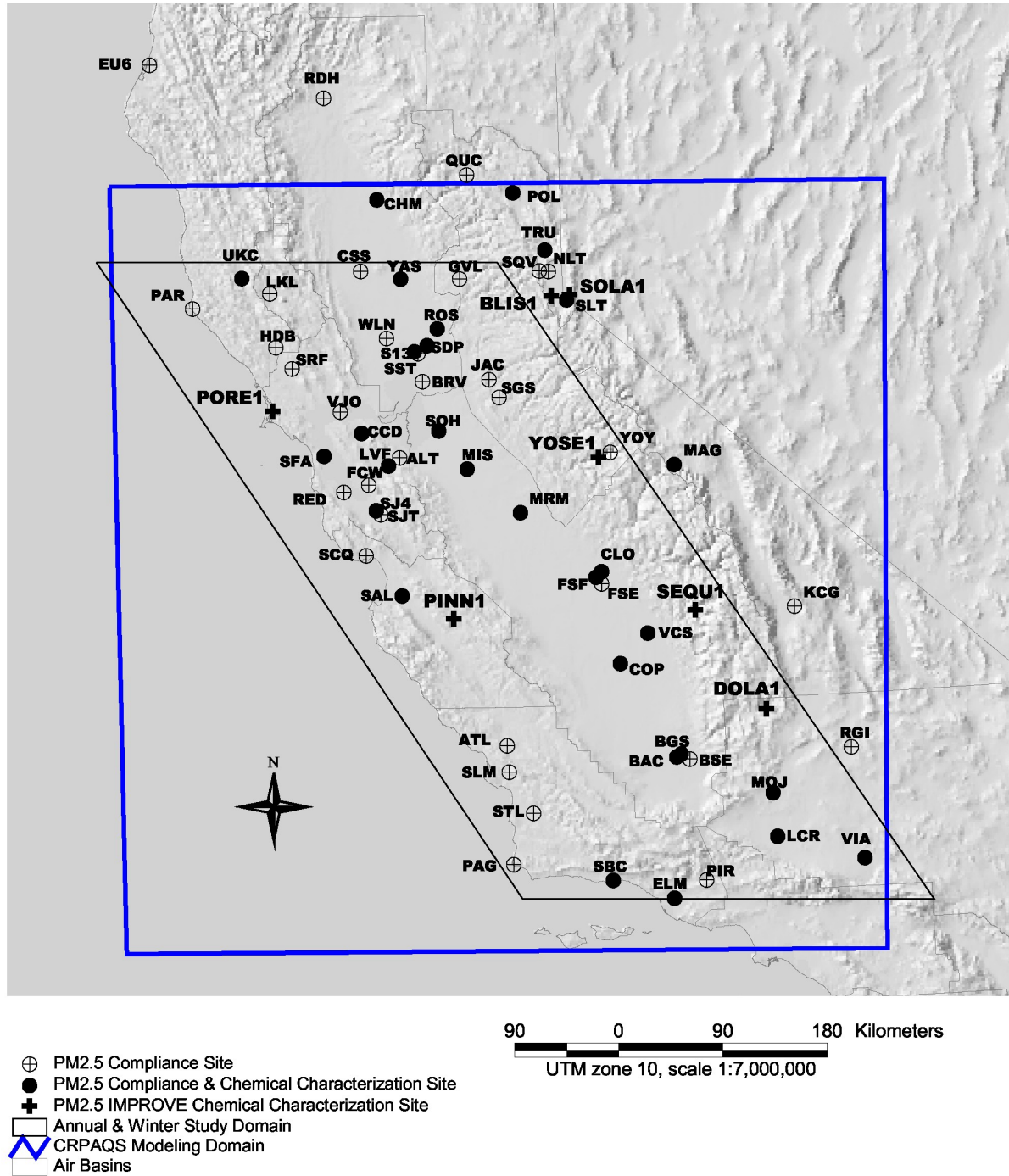
#### 3.1 Task 4.4.1 – Determine Diurnal, Temporal, and Spatial Variations in Source Contributions

To answer Question 4.4-2 on the variability in chemical concentrations and Question 4.4-4 on temporal and spatial variations, statistics (averages, maxima, minima, 5th percentiles, and 95th percentiles) for different sampling periods (3-hour, 5-hour, 8-hour, 24-hour, seasonal averages, and annual averages) at each site will be generated to examine diurnal, temporal, and spatial variations of source contribution estimates. Time-weighted source contribution estimates derived from 5 times/day samples acquired by DRI sequential filter samplers will be compared with average source contribution estimates derived from 24-hour samples acquired by Airmetrics Minivol samplers for collocated measurements acquired at the Bethel Island and Sierra Foothill sites during the winter intensive period.

**Figure 4.4-1.** The CRPAQS aerosol monitoring network.



**Figure 4.4-2.** ARB backbone PM<sub>2.5</sub> network with Federal Reference Method (FRM) mass measurement and chemical speciation sites. IMPROVE visibility sites are separately designated. The heavy continuous line represents the modeling domain, while the light continuous line represents the annual and winter measurement domain.



**Table 4.4-1.** Summary of CRPAQS anchor site measurements applicable to CMB source apportionment.

	Sampling Sites	Sampling Period	# of Sampling Days	Sampling Interval <sup>a</sup>	PM precursor gases <sup>b</sup>	PM <sub>2.5</sub> mass, elements, ions, and carbon <sup>c</sup>	C <sub>2</sub> -C <sub>12</sub> volatile organic compounds (VOC) <sup>d</sup>	C <sub>8</sub> -C <sub>20</sub> volatile organic compounds (VOC) <sup>e</sup>	Carbonyls <sup>f</sup>	Particulate and semivolatile and particulate organic compounds (SVOC and organics) <sup>g</sup>	Estimated total number of CMB runs			
											Conventional Method		with Speciated Organics	Total # of CMB runs
											PM <sub>2.5</sub>	VOC		
Annual	Fresno Angiola Bakersfield	12/03/99 to 02/03/01	413	Daily 24-hr samples	data not available	300 <sup>j</sup>	data not available	data not available	data not available	3 <sup>k</sup>	300 <sup>j</sup>	0	data not available	300
Winter Intensive	Bethel Island Sierra Foothill Fresno Angiola Bakersfield	12/15/00 to 02/03/01	15 <sup>h</sup>	3-, 5-, and 8-hr samples at 5 times/day for PM <sub>2.5</sub> and precursor gases, and 2 to 4 times/day for organics	375	471 <sup>i</sup>	240	140	240	140	471 <sup>i</sup>	240	140	851
Summer Intensive	Fresno	06/29/00 to 09/05/00	10 <sup>l</sup>	Daily 24-hr samples		10		10		10	10	0	10	20

<sup>a</sup> PM<sub>2.5</sub>, ammonia, and nitric acid were sampled 5 times/day (0000-0500, 0500-1000, 1000-1300, 1300-1600, and 1600-2400 PST) at 5 anchor sites (Bethel Island, Sierra Foothill, Fresno, Angiola, and Bakersfield). VOCs (C<sub>2</sub> to C<sub>12</sub>) and carbonyls were sampled 4 times/day (0000-0500, 0500-1000, 1000-1600, and 1600-2400 PST) at 4 anchor sites (Angiola, Fresno, Bethel Island, and Sierra Foothill). VOCs (C<sub>8</sub> to C<sub>20</sub>) and SVOC/particulate organics were sampled 4 times/day (0000-0500, 0500-1000, 1000-1600, and 1600-2400 PST) at the Fresno site and 2 times/day (0500-1600 and 1600-next day 0500 PST) at the Bethel Island, Sierra Foothill, and Angiola sites.

<sup>b</sup> Gaseous ammonia and nitric acid samples were acquired with sequential gas samplers (SGS) using the denuder difference method. Samples were analyzed for NH<sub>4</sub><sup>+</sup> by automated colorimetry and for NO<sub>3</sub> by ion chromatography.

<sup>c</sup> PM<sub>2.5</sub> samples were collected with DRI medium-volume sequential filter samplers (SFS). Teflon-membrane filter samples were analyzed for mass by gravimetry, filter transmission (b<sub>abs</sub>) by densitometry, and elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Tl, Pb, and U) by x-ray fluorescence (Watson et al., 1999); quartz-fiber filter samples were analyzed for anions (Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>) by ion chromatography (Chow and Watson, 1999), ammonium by automated colorimetry, water-soluble Na<sup>+</sup> and K<sup>+</sup> by atomic absorption spectrophotometry, and 7-fraction organic and elemental carbon (OC1 combusted at 120 °C, OC2 at 250 °C, OC3 at 450 °C, OC4 at 550 °C, EC1 at 550 °C, EC2 at 700 °C, and EC3 at 800 °C with pyrolysis correction) by thermal/optical reflectance (Chow et al., 1993b, 2001); citric-acid-impregnated filter samples were analyzed for ammonia by automated colorimetry; and sodium-chloride-impregnated filters were analyzed for volatilized nitrate by ion chromatography.

<sup>d</sup> C<sub>2</sub> to C<sub>12</sub> VOC samples were acquired with canister samplers. Samples were analyzed by Dr. Reinhold Rasmussen at the Oregon Graduate Institute of Science and Technology, Portland, OR, using gas chromatography with mass spectrometry to determine concentrations of 123 VOCs:

propene	n-butane	c-2-butene	1-pentene	t-2-pentene
propane	methanol	3-methyl-1-butene	2-methyl-1-butene	c-2-pentene
isobutane	t-2-butene	ethanol	n-pentane	2-methyl-2-butene
1,3-butadiene	1&2-butyne	isopentane	isoprene	2,2-dimethylbutane

cyclopentene	2,2,3-trimethylbutane	toluene	1-nonene	indan
4-methyl-1-pentene	1-methylcyclopentene	2,3-dimethylhexane	n-nonane	indene
3-methyl-1-pentene	benzene	2-methylheptane	isopropylbenzene	1,3-diethylbenzene
cyclopentane	3,3-dimethylpentane	4-methylheptane	isopropylcyclohexane	1,4-diethylbenzene
2,3-dimethylbutane	cyclohexane	3-methylheptane	2,6-dimethyloctane	n-butylbenzene
methyl-t-butylether	4-methylhexene	2,2,5-trimethylhexane	alpha-pinene	1,2-diethylbenzene
2-methylpentane	2-methylhexane	octene-1	3,6-dimethyloctane	1,3-dimethyl-4-ethylbenzene
2,2-dimethylpentane	2,3-dimethylpentane	1,1-dimethylcyclohexane	n-propylbenzene	isopropyltoluene
3-methylpentane	cyclohexene	n-octane	m-ethyltoluene	nonanal
2-methyl-1-pentene	3-methylhexane	2,3,5-trimethylhexane	p-ethyltoluene	1-undecene
1-hexene	1,3-dimethylcyclopentane	2,4-dimethylheptane	1,3,5-trimethylbenzene	n-undecane
n-hexane	3-ethylpentane	4,4-dimethylheptane	o-ethyltoluene	1,2,4,5-tetramethylbenzene
t-3-hexene	1-heptene	2,6-dimethylheptane	octanal	1,2,3,5-tetramethylbenzene
t-2-hexene	2,2,4-trimethylpentane	2,5-dimethylheptane	beta-pinene	1,2,3,4-tetramethylbenzene
2-methyl-2-pentene	t-3-heptene	3,3-dimethylheptane	1-decene	2-methylindan
cis-3-methyl-2-pentene	n-heptane	ethylbenzene	1,2,4-trimethylbenzene	1-methylindan
c-3-hexene	2,4,4-trimethyl-1-pentene	m- & p-xylene	n-decane	1-dodecene
c-2-hexene	methylcyclohexane	2-methyloctane	isobutylbenzene	naphthalene
trans-3-methyl-2-pentene	2,5-dimethylhexane	3-methyloctane	sec-butylbenzene	n-dodecane
methylcyclopentane	2,4-dimethylhexane	styrene	1,2,3-trimethylbenzene	
2,4-dimethylpentane	2,3,4-trimethylpentane	o-xylene	limonene	

<sup>e</sup> C<sub>8</sub> to C<sub>20</sub> volatile organic compound samples were acquired with glass cartridges filled with Tenax-TA (a polymer of 2,6-diphenyl-p-phenylene oxide) solid adsorbent. Samples were analyzed by the thermal desorption/cryogenic preconcentration method followed by high-resolution gas chromatography separation and flame ionization detection and/or combined mass spectrometry/Fourier transform infrared detection for 63 VOCs:

1,2,4,5-tetramethylbenzene	1-methyl-3-(1-methylethyl)benzene	1-methyl-2-n-propylbenzene	nonanal	ethanone-1(3-methoxyphenol)
1(1,1-dimethylethyl)3-5-dimethylbenzene	n-pentylbenzene	1-methyl-3-n-propylbenzene	decanal	t-2,4-decadienal
(1-methylethyl)benzene	(2-methylpropyl)benzene	1-methyl-4-n-propylbenzene	undecanal	Undecane
1-methyl-4-(1-methylethyl)benzene	1-methyl-2-ethylbenzene	1-methyl-2-n-butylbenzene	dodecanal	dodecane
1,4-diethylbenzene	1-methyl-3-ethylbenzene	1,4-dimethyl-2-ethylbenzene	tridecanal	tridecane
1,2-diethylbenzene	1-methyl-4-ethylbenzene	1,3-dimethyl-2-ethylbenzene	Tetradecanal	tetradecane
1,3-diethylbenzene	4-methylindan	1-ethyl-2-n-propylbenzene	Pentadecanal	pentadecane
(1-methylpropyl)benzene	2-methylindan	1,3-di-n-propylbenzene	Hexadecanal	hexadecane
1,2,3,4-tetramethylbenzene	5-methylindan	2-methylnaphthalene	Octadecanal	heptadecane
2,3-dihydroindene (indan)	1,3-dimethyl-4-ethylbenzene	1-methylnaphthalene	2-furaldehyde	octadecane
1,2,3,5-tetramethylbenzene	1,2-dimethyl-3-ethylbenzene	hexanal	benzaldehyde	nonadecane
1-methyl-2-(1-methylethyl)benzene	1,3-dimethyl-5-ethylbenzene	heptanal	acetophenone	eicosane
	1,2-dimethyl-4-ethylbenzene	octanal	2,5-dimethylbenzaldehyde	

<sup>f</sup> Carbonyl samples were acquired with AtmAA sequential carbonyl samplers containing dinitrophenylhydrazine (DNPH) cartridges. Cartridges were analyzed by Dr. Kochy Fung at AtmAA Environmental Consultants, Calabasas, CA, using high-performance liquid chromatography to determine concentrations of 14 carbonyls (formaldehyde, acetaldehyde, acetone, acrolein, propanal, crotonal, methyl ethyl ketone, methacrolein, butanal, pentanal, glyoxal, hexanal, benzaldehyde, and m-tolualdehyde).

<sup>g</sup> Semivolatile organic compounds and particulate organics were acquired with a sampling train consisting of a Teflon-impregnated glass fiber filter backed up with a PUF/XAD-4/PUF sandwich solid adsorbent. Samples were analyzed by gas chromatography with mass spectrometry for 151 particulate and semivolatile VOCs:



<u>Naphthalene</u>	Benz(a)anthracene	9-anthraldehyde		n-tricosane
2-menaphthalene	7-methylbenz[a]anthracene	Benzanthrone	<u>Carpanes</u>	n-tetracosane
1-menaphthalene	Chrysene/triphenylene	Benz(a)anthracene-7,12-dione	8 , 13 -Dimethyl-14 -n-butylpodocarpane	n-pentacosane
2,6+2,7-dimenaphthalene	Benzo(b+j+k)FL	1,4-chrysenequinone	8 , 13 Dimethyl-14 -[3'-methylbutyl] podocarpane	n-hexacosane
1,7+1,3+1,6-dimenaphthalene	BeP	9,10-dihydrobenzo(a)pyren-7(8H)-one	n-Alkanoic Acids	n-heptacosane
2,3+1,4+1,5-dimenaphthalene	BaP	Nitro-PAH	octanoic acid	n-octacosane
1,2-dimenaphthalene	7-methylbenzo[a]pyrene	1-Nitronaphthalene	nonanoic acid	farnesane
1,8-dimenaphthalene	indeno[123-cd]pyrene	2-Nitronaphthalene	decanoic acid	norpristane
Biphenyl	dibenz(ah+ac)anthracene	Methylnitronaphthalenes	undecanoic acid	norfarnesane
2-methylbiphenyl	Benzo(b)chrysene	2-Nitrobiphenyl	dodecanoic acid	pristane
3-methylbiphenyl	Benzo(ghi)perylene	4-Nitrobiphenyl	tridecanoic acid	phytane
4-methylbiphenyl	coronene	5-Nitroacenaphthene	tetradecanoic acid	
Trimethylnaphthalene Isomers	4Hcyclopenta(def)phenanthrene	2-Nitrofluorene	heptadecanoic acid	<u>Saturated Cycloalkanes</u>
Ethyl-Methylnaphthalenes	benzo(c)phenanthrene	9-Nitroanthracene	octadecanoic acid	tridecylcyclohexane
Acenaphthylene	Perylene	1-Nitropyrene	nonadecanoic acid	tetradecylcyclohexane
Acenaphthene	quinoline	4-Nitropyrene	eicosanoic acid	pentadecylcyclohexane
phenanthrene	dibenzo[a,e]pyrene	3-Nitrofluoranthene	Alkanedioic acids	hexadecylcyclohexane
Fluorene	dibenzo[a,h]pyrene	7-Nitrobenz(a)anthracene	octadecanedioic acid	heptadecylcyclohexane
Methylfluorenes Isomers	dibenzo[a,i]pyrene	6-Nitrochrysene	nonadecanedioic acid	octadecylcyclohexane
1-methylfluorene	dibenzo[a,l]pyrene	6-Nitrobenzo(a)pyrene		nonadecylcyclohexane
Methylphenanthrenes Isomers	dibenz[a,j]acridine	1,8-Dinitropyrene	<u>Aromatic acids</u>	
2-methylphenanthrene	dibenz[a,h]acridine	1,6-Dinitropyrene	benzoic acid	<u>Lower priority cycloalkanes</u>
1-methylphenanthrene	7H-dibenzo[c,g]carbazole	1,3-Dinitropyrene	methylbenzoic acid	heptylcyclohexane
3,6-dimethylphenanthrene	5-methylchrysene			octylcyclohexane
1,7-dimethylphenanthrene	dibenz[a,h]anthracene	<u>Hopanes&amp;Steranes</u>		nonylcyclohexane
Anthracene	7,12-dimethylbenzanthracene	18 (H)-22,29,30-trisnorhopane	<u>Alkanes</u>	decylcyclohexane
9-methylanthracene	3-methylcholanthrene	17 (H)-22,29,30-trisnorhopane	n-pentadecane	undecylcyclohexane
fluoranthene	Oxy-PAH	17 (H)-21 (H)-29-norhopane	n-hexadecane	dodecylcyclohexane
pyrene	9-fluorenone	17 (H)-21 (H)-hopane	n-heptadecane	eicosylcyclohexane
Methylpyrene/fluoranthenes	Xanthone	20R,5 (H),14 (H),17 (H)-cholestane	n-octadecane	heneicosylcyclohexane
4-methylpyrene	Acenaphthenequinone	20R,5 (H),14 (H),17 (H)-cholestane	n-nonadecane	
retene	Perinaphthenone	20R&S,5 (H),14 (H),17 (H)-ergostane	n-eicosane	
Benzonaphthothiophene	Anthraquinone	20R&S,5 (H),14 (H),17 (H)-sitostane	n-heneicosane	
			n-docosane	

<sup>h</sup> 15 forecast episode days were 12/15/00 to 12/18/00, 12/26/00 to 12/28/00, 01/04/01 to 01/07/01, and 01/31/01 to 02/03/01.

<sup>i</sup> Including 358 PM<sub>2.5</sub> samples from winter intensive sampling at the 5 anchor sites (Fresno, Bakersfield, Angiola, Bethel Island, and Sierra Foothill) and 113 samples collected on 23 additional days (12/19/00 to 12/25/00, 12/29/00 to 01/03/01, and 01/08/01 to 01/17/01), resulting in daily, 5 times/day samples from 12/15/00 to 01/17/01, and CRPAQS last episode (01/31/01 to 02/03/01) funded by a collaborative study with U.S. EPA/Battelle's Environmental Technology Verification Program.

<sup>j</sup> 100 PM<sub>2.5</sub> samples per site (from every-sixth-day sampling during the 14-month annual program and from selected episode days) were analyzed.

<sup>k</sup> Composite of 61 individual samples acquired on an every-sixth-day schedule between 02/06/00 and 01/31/01 from a total of 20 sites (including 3 annual anchor sites [Fresno, Angiola, and Bakersfield], 14 annual satellite sites, the San Jose-4th St. [SJ4] site, the Sacramento-Del Paso Manor [SPP] site, and the Yosemite [YOSE1] site) with Minivol samplers (Airmetrics, Eugene, OR) equipped with PM<sub>2.5</sub> inlets and Teflon-impregnated glass-fiber filters. Samples were analyzed by gas chromatography with mass spectrometry for up to 151 particulate organic compounds as listed in footnote g above.

<sup>l</sup> Sampling was done on 10 forecast summer episode days (06/29/00, 07/05/00, 07/11/00, 07/17/00, 07/19/00, 08/16/00, 08/22/00, 08/28/00, 09/03/00, and 09/05/00).

**Table 4.4-2.** Summary of CRPAQS satellite site measurements applicable to CMB source apportionment.

	Number of Sampling Sites <sup>a</sup>	Sampling Period	Number of Sampling Days	Conventional Method CMB	CMB with Speciated Organics
Annual PM <sub>2.5</sub> (every sixth day, 24-hr sampling)	29	12/02/99 to 02/03/01	71	1,944	14 <sup>b</sup>
Annual PM <sub>10</sub> (every sixth day, 24-hr sampling)	7	12/02/99 to 02/03/01	71	497	0
Annual PM <sub>2.5</sub> organics (every sixth day, 24-hr sampling)	17	02/06/00 to 01/31/01	composite of 61 days	0	3 <sup>c</sup>
Winter intensive PM <sub>2.5</sub> (daily sampling on 13 episode days)	21	12/15/00 to 02/03/01	13	254	0
Fall intensive PM <sub>10</sub> (daily, 24-hr sampling)	6	10/09/00 to 11/14/00	37	193	0
Total number of CMB analyses				3,029	17

<sup>a</sup> See Table 4.1-6 for measurement methods and sampling locations.

<sup>b</sup> See Table 4.1-6 for a list of the 14 annual sites sampled with Teflon-impregnated glass-fiber filters (TIGF) and collocated PM<sub>2.5</sub> chemistry sites.

<sup>c</sup> No concurrent PM<sub>2.5</sub> measurements were taken at the San Jose–4th St. (SJ4), Sacramento–Del Paso Manor (SDP), or Yosemite (YOSE1) sites.

**Table 4.4-3.** Summary of CRPAQS satellite site aerosol measurements applicable to CMB source apportionment.<sup>a</sup>

Site Code	Site Name	Site Type	Filter Pack Configuration					Sampling Period		
			PM <sub>2.5</sub>		PM <sub>2.5</sub> Organics	PM <sub>10</sub>		Annual <sup>e</sup>	Fall Intensive <sup>f</sup>	Winter Intensive <sup>g</sup>
			T/C	q/n	TIGF	T/c	Q/n			
		<i>Minivol module →</i>	A <sup>h</sup>	B <sup>i</sup>	D <sup>j</sup>	g <sup>k</sup>	h <sup>l</sup>			
ACP	Angels Camp	Intrabasin Gradient	FTC	FQN				X		X
BGS	Bakersfield-1120 Golden State	Community Exposure				TTC	TQN	(X)		
BODG	Bodega Marine Lab	Boundary/Background	FTC	FQN				X		X
BRES	BAC-Residential	Source- woodburning	FTC	FQN				X		X
BTI	Bethel Island	Interbasin Transport	FTC	FQN	TIGF			X		
CHL	China Lake	Visibility	FTC	FQN	TIGF			X		
CLO	Clovis	Community Exposure	FTC	FQN				X		X
COP	Corcoran-Patterson Avenue	Community Exposure	FTC	FQN	TIGF	TTC	TQN	(X)	X	X
EDW	Edwards Air Force Base	Intrabasin Gradient, Visibility	FTC	FQN	TIGF			X		
FEDL	Feedlot or Dairy	Source - Cattle	FTC	FQN	TIGF			X		X
FEL	Fellows	Source- Oilfields	FTC	FQN	TIGF			X		X
FELF	Foothills above Fellows	Intrabasin Gradient	FTC	FQN				X		X
FREM	Fresno MV	Source - Motor Vehicle	FTC	FQN				X		X
FRES	Residential area near FSF, with woodburning	Source - Woodburning	FTC	FQN	TIGF			X		X
FSD	Fresno Drummond	Community Exposure				TTC	TQN	(X)		
GRA	Grain Elevator	Source - Grain Elevators				TTC	TQN		X	
GRAS	Grain Elevator South	Source - Zone of Influence				TTC	TQN		X	
H43	Highway 43	Southern Boundary				TTC	TQN		X	
HAN	Hanford-Irwin St.	Community Exposure and Fall Northern Boundary				TTC	TQN	(X)	X	
HELM	Agricultural fields/Helm-Central Fresno County	Intrabasin Gradient	FTC	FQN	TIGF			X		X
LVR1	Livermore - New site	Interbasin Transport	FTC	FQN	TIGF			X		X
M14	Modesto 14th St.	Community Exposure	FTC	FQN	TIGF	TTC	TQN	(X)		X
MOP	Mojave-Poole	Community Exposure	FTC	FQN				X		
MRM	Merced-midtown	Community Exposure	FTC	FQN				X		X
OLD	Oildale-Manor	Community Exposure	FTC	FQN		TTC	TQN	(X)		
OLW	Olancha	Background	FTC	FQN	TIGF			X		X
PIXL	Pixley Wildlife Refuge	Rural, Intrabasin Gradient	FTC	FQN	TIGF			X		X

**Table 4.4-3.** (continued)

Site Code	Site Name	Site Type	Filter Pack Configuration					Sampling Period		
			PM <sub>2.5</sub>		PM <sub>2.5</sub> Organics	PM <sub>10</sub>		Annual <sup>e</sup>	Fall Intensive <sup>f</sup>	Winter Intensive <sup>g</sup>
			T/C	q/n	TIGF	T/c	Q/n			
		<i>Minivol module →</i>	A <sup>h</sup>	B <sup>i</sup>	D <sup>j</sup>	g <sup>k</sup>	h <sup>l</sup>			
PLE	Pleasant Grove (north of Sacramento)	Intrabasin Gradient	FTC	FQN				X		
S13	Sacramento-1309 T Street	Community Exposure	FTC	FQN	TIGF			X		X
SDP	Sacramento-Del Paso Manor	Community Exposure			TIGF			X		
SELM	Selma(south Fresno area gradient site)	Community Exposure	FTC	FQN				X		X
SFA	San Francisco - Arkansas	Community Exposure	FTC	FQN				X		
SFE	Santa Fe Street	Source - Cotton Handling				TTC	TQN		X	
SJ4	San Jose-4th Street	Community Exposure			TIGF			X		
SNFH	Sierra Nevada Foothills	Vertical Gradient, Intrabasin Gradient, Visibility	FTC	FQN	TIGF			X		
SOH	Stockton-Hazelton	Intrabasin Gradient	FTC	FQN				X		X
SWC	SW Chowchilla	Interbasin Transport	FTC	FQN				X		X
VCS	Visalia Church St.	Community Exposure	FTC	FQN		TTC	TQN	(X)		X
YOSE1	Yosemite National Park-Turtleback Dome	Boundary/Background, Visibility			TIGF			X		
			-----	-----	-----	-----	-----	-----	-----	-----
		Total Number of Sites	29	29	17 (14 annual plus 3 single TIGF sites)	11	11	35	6	21
		15 community exposure sites (BGS, CLO, COP, FSD, HAN, M14, MOP, MRM, OLD, S13, SDP, SELM, SFA, SJ4, and VCS))								
		8 emissions source dominated sites (BRES, FEDL, FEL, FREM, FRES, GRA, GRAS, and SFE))								
		4 visibility sites (CHL, COP, SNFH, and YOSE1)								
		8 intrabasin gradient sites (ACP, EDW, FELF, HELM, PIXL, PLE, SNFH, and SOH)								
		1 vertical gradient site (SNFH)								
		3 interbasin transport sites (BTI, LVR1, and SWC)								
		6 boundary/background sites (BODG, H43, HAN, OLW, PIXL, and YOSE1)								

<sup>a</sup> Teflon-membrane filter samples were analyzed for mass by gravimetry, filter transmission (b<sub>abs</sub>) by densitometry, and elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Tl, Pb, and U) by x-ray fluorescence (Watson et al., 1999); quartz-fiber filter samples were analyzed for anions (Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>-</sup>) by ion chromatography (Chow and Watson, 1999), ammonium by automated colorimetry, water-soluble Na<sup>+</sup> and K<sup>+</sup> by atomic absorption spectrophotometry, and 7-fraction organic and

elemental carbon (OC1 combusted at 120 °C, OC2 at 250 °C, OC3 at 450 °C, OC4 at 550 °C, EC1 at 550 °C, EC2 at 700 °C, and EC3 at 800 °C with pyrolysis correction) by thermal/optical reflectance (Chow et al., 1993b, 2001); citric-acid-impregnated filter samples were analyzed for ammonia by automated colorimetry; and sodium-chloride-impregnated filters were analyzed for volatilized nitrate by ion chromatography.

- <sup>b</sup> Sampling with battery-powered Minivol samplers (Airmetrics, Eugene, OR) equipped with PM<sub>10</sub>/PM<sub>2.5</sub> (in tandem) or PM<sub>10</sub> inlets at a flow rate of 5 L/min.
- <sup>c</sup> Anchor site annual sampling program used DRI medium-volume sequential filter samplers (SFS) equipped with Bendix 240 cyclone PM<sub>2.5</sub> inlets and preceding anodized aluminum nitric acid denuders. Sampling was conducted daily, 24 hours/day (midnight to midnight) from 12/02/99 to 02/03/01 at a flow rate of 20 L/min. Two filter packs were used for sampling: 1) each Teflon/citric acid filter pack consists of a front Teflon-membrane filter (for mass, b<sub>abs</sub>, and elemental analyses) backed up by a citric-acid-impregnated cellulose-fiber filter (for ammonia), and 2) each quartz/NaCl filter pack consists of a front quartz-fiber filter (for ion and carbon analyses) backed up by a sodium-chloride-impregnated cellulose-fiber filter (for volatilized nitrate).
- <sup>d</sup> The seven PM<sub>10</sub> sites operated during the annual program are noted with (X). Satellite site annual sampling program included every-sixth-day 24-hour sampling at 35 PM<sub>2.5</sub> sites and 7 PM<sub>10</sub> sites between 12/02/99 and 02/03/01. PM<sub>2.5</sub> particulate organic compounds were sampled at 20 sites between 02/06/00 and 01/31/01.
- <sup>e</sup> Satellite site fall intensive study included 24-hour sampling of PM<sub>10</sub> on 37 days between 10/09/00 and 11/14/00 at 11 sites. 6 sites (COP, H43, HAN, GRA, GRAS, and SFE) were equipped with both Teflon/citric acid and quartz/NaCl filter packs. 5 sites (CO5, DAIP, DAIU, ORE, and YOD) were equipped with only Teflon/citric acid filter packs.
- <sup>f</sup> Satellite site winter intensive study included 24-hour sampling of PM<sub>2.5</sub> on 13 forecast episode days (12/15/00 to 12/18/00, 12/25/00, 12/27/00, 12/28/00, 01/04/01 to 01/06/01, and 02/01/01 to 02/03/01) at 25 PM<sub>2.5</sub> sites, with 21 of the sites equipped with both Teflon/citric acid and quartz/NaCl filter packs.
- <sup>g</sup> Minivol module A: PM<sub>2.5</sub> Teflon/citric acid filter packs at 35 satellite sites. Each filter pack consisted of a front Teflon-membrane filter (for mass, b<sub>abs</sub>, and elements) backed up by a citric-acid-impregnated cellulose-fiber filter (for ammonia).
- <sup>h</sup> Minivol module B: PM<sub>2.5</sub> quartz/NaCl filter packs at 29 satellite sites (same sites as module A but excluding ALT1, PAC1, KCW, EDI, CARP, and TEH2). Each filter pack consisted of a front pre-fired quartz-fiber filter (for ions and carbon) backed up by a sodium-chloride-impregnated cellulose-fiber filter (for volatilized nitrate).
- <sup>i</sup> Minivol module D: PM<sub>2.5</sub> Teflon-impregnated glass-fiber filters (TIGF) at a total of 20 sites (including 3 annual anchor sites [Fresno, Angiola, and Bakersfield], 14 annual satellite sites, the San Jose-4th St. [SJ4] site, the Sacramento-Del Paso Manor [SPP] site, and the Yosemite [YOSE1] site). A total of 61 samples acquired over the yearlong sampling period were composited as one sample and analyzed by gas chromatography with mass spectrometry (GC/MS) for up to 151 particulate organic compounds as listed in footnote d above.
- <sup>j</sup> Minivol module g: PM<sub>10</sub> Teflon/citric acid filter packs at 16 satellite sites, 4 of which (M14, VCS, COP, and OLD) were collocated with annual PM<sub>2.5</sub> measurements, and 7 of which (M14, VCS, COP, FSD, BGS, HAN, and OLD) were annual PM<sub>10</sub> sites. Each filter pack consisted of a front Teflon-membrane filter (for mass, b<sub>abs</sub>, and elements) backed up by a citric-acid-impregnated cellulose-fiber filter (for ammonia).
- <sup>k</sup> Minivol module h: PM<sub>10</sub> quartz/NaCl filter packs at 16 satellite sites, 4 of which were collocated with annual PM<sub>2.5</sub> measurements (M14, VCS, COP, and OLD), and 7 of which (M14, VCS, COP, FSD, BGS, HAN, and OLD) were annual PM<sub>10</sub> sites. Each filter pack consisted of a front quartz-fiber filter (for ion and carbon analyses) backed up by a sodium-chloride-impregnated cellulose-fiber filter (for volatilized nitrate).
- <sup>l</sup> One of six sites (ALT1, PAC1, KCW, EDI, CARP, and TEH2) where only Minivol module A Teflon/citric acid filter packs were acquired.

Time series plots of PM source attributions during pollution buildup periods and for sites on days when maximum concentrations occurred will be examined. Primary and secondary source contribution estimates at each site will be compared, and differences and similarities among source contribution estimates from each of the 8 site-type categories summarized in Table 4.4-3 (e.g., community exposure, emissions source dominated, visibility, intrabasin gradient, vertical gradient, intrabasin transport, interbasin transport, boundary/background) will be evaluated. Spatial pie plots or stacked bar charts of source contribution estimates for annual, seasonal, episodic, and maximum periods coupled with emission and meteorological data will be evaluated.

### **3.2 Task 4.4.2 – Determine Source Zones of Influence and Receptor Zones of Representation**

Monitoring sites should be selected to represent several spatial scales as defined below (U.S. Environmental Protection Agency, 1997). Distances indicate the diameter of a circle, or the length and width of a grid square, with a monitor at its center.

- Collocated or Indoor Scale or Ducted Emissions (1 to 10 m)
- Microscale (10 to 100 m)
- Middle Scale (100 to 500 m)
- Neighborhood Scale (500 m to 4 km)
- Urban Scale (4 to 100 km)
- Regional-Scale Background (100 to 1,000 km)
- Continental-Scale Background (1,000 to 10,000 km)
- Global-Scale Background (>10,000 km)

The zone of representation for a monitoring site is often not evident in the absence of measurements or modeling results from nearby locations. To address Question 4.4-1 on spatial homogeneity and zones of influence and Question 4.4-4 on temporal and spatial variations of source contribution estimates, spatial averages of source contribution estimates (bracketed by neighborhood, urban, and regional scales) will first be calculated to determine the temporal and spatial coefficients and characteristics. These coefficients will be compared with results from Task 3.1 where major chemical components are used to examine temporal and spatial variations. Similarities and differences will be explained.

Spatial contour plots for source contribution estimates will be generated with an “inverse distance to a power” gridding method using *Surfer 6.01* (Golden Software, Golden, CO). This method is a weighted average interpolator in which data points are weighted such that the influence of one data point relative to another declines with distance from the grid

node. Normally, the inverse distance method behaves as an exact interpolator. The weighted average interpolator has a tendency to generate “bull’s eye” patterns of concentric contours around the data points, and a smoothing parameter can be assigned to generate the contour plot. Spatial homogeneity and scales of influence should be different for primary and secondary source contributions and for sites with and without local influences. Differences among source contribution estimates in urban areas and in subregional background areas will be compared, and urban plumes that are superimposed at neighborhood and urban sites will be determined.

### **3.3 Task 4.4.3 – Evaluate Spatial Scales of Influence on Compliance (Backbone) Sites**

Table 4.4-4 summarizes the 68 PM<sub>2.5</sub> backbone sites in central California’s compliance monitoring network that are within the measurement and modeling domain of CRPAQS (shown in Figure 4.4-2). A subset of backbone sites that are surrounded with satellite sites (e.g., Sacramento [S13], Stockton [SOH], San Francisco [SFA], San Jose [SJ4], Modesto [M14], Clovis [CLO], Visalia [VIS], Corcoran [COP], and Mojave [MOJ]) will be used to determine source contribution levels. Backbone sites will be superimposed on a spatial contour map of source contribution estimates for each source type (from Task 4.4.2) to determine source contribution levels from each source type. The sum of source contribution estimates at nearby satellite sites will be compared with measured PM<sub>2.5</sub> mass at the corresponding backbone sites to see whether mass closure can be achieved. Discrepancies will be verified, and spatial scales of influence will be compared with those from nephelometer measurements of particle light scattering and other continuous measurements (from Tasks 3.1 and 3.2), and with those from PM material balances (derived from major chemical components) at the anchor and satellite sites. Any differences will be reconciled.

Another approach complementing the spatial correlation plots is the use of geostatistics and kriging, which were originally developed in the early 1960’s for the estimation of ore reserves in the mining industry. This technique has more recently been extended to include several disciplines in the earth (Juang and Lee, 1998), hydrological (Chang et al., 1998), and atmospheric sciences (Shindo et al., 1990; Schaug et al., 1993; Casado et al., 1994; Sen, 1995; Buckley, 1997; Stedman et al., 1997), and is suited to any spatial or three-dimensional data sets.

The objectives of geostatistical estimation for this analysis are:

- To characterize and interpret the behavior of source contribution estimates for each source type.
- To estimate by interpolation probable source contributions at locations which have not been sampled.

**Table 4.4-4.** PM<sub>2.5</sub> mass and chemical measurements acquired from the central California backbone network.

Site Code <sup>a</sup>	Site Name	Site Type <sup>a</sup>	Sampling Frequency	PM <sub>2.5</sub> Sampler <sup>b</sup>	Speciation Sampler <sup>c</sup>
ALT	Altamont Pass-Tracy	S	1 in 3		
ATL	Atascadero-Lewis Ave	C	1 in 6	(X)	
BGS <sup>d</sup>	Bakersfield-1120 Golden State	C	1 in 3	X	S
BAC <sup>d</sup>	Bakersfield-5558 California Ave	C	every day	(X)	S
BLIS1	D.L. Bliss State Park-TRPA	I	1 in 3	I	
BRV	Elk Grove-Bruceville Rd	C	1 in 3		
BSE	Bakersfield-Southeast (410 E. Planz)	C	1 in 3	X	
CCD	Concord-2975 Treat Blvd	C	every day	(X)	S
CHM	Chico-Manzanita Ave	C	1 in 6	X	S
CLO <sup>d</sup>	Clovis-908 N Villa Ave	C	1 in 3	X	S
COP <sup>d</sup>	Corcoran-Patterson Ave	C	1 in 3	X	S
CSS	Colusa-100 Sunrise Blvd	C	1 in 3	X	
DOLA1 <sup>e</sup>	Dome Land Wilderness-USFS	I	1 in 3	I	
ELM	El Rio-Mesa School #2	C	1 in 3	X	S
EU6	Eureka-Health Dept	C	1 in 6	X	
FCW	Fremont-Chapel Way	C	1 in 3	X	
FSE	Fresno-Southeast (Pacific College)	C	1 in 3	X	
FSF <sup>d</sup>	Fresno-3425 First Street	C	every day	(X)	S
GVL	Grass Valley-Litton Building Site	C	1 in 6	X	
HDB	Healdsburg-Limeric Lane	C	1 in 6		
JAC	Jackson-201 Clinton Road	C	1 in 3		
KCG	Keeler-Cerro Gordo Road	C	1 in 3	(X)	
LCR	Lancaster-W Pondera Street	C	1 in 3	X	S
LKL	Lakeport-Lakeport Blvd	C	1 in 6	X	
LTY	South Lake Tahoe-Sandy Way	C	1 in 6	(X)	S
LVF	Livermore (793 Rincon Ave.)	C	1 in 3	X	S
MAG	Mammoth Lakes-Gateway HC	C	1 in 3	X	S
M14	Modesto-14th St.	C	1 in 3	X	S
MOJ	Mojave-923 Poole Street	C	1 in 3	X	S
MRM <sup>d</sup>	Merced-Midtown	C	1 in 3	X	S
NLT	North Lake Tahoe-Near Tahoe City (Echo Summit)	C	1 in 3	X	
PAG	Point Arguello	S	1 in 3		
PARN	Point Arena	S	1 in 3		
PINN1	Pinnacles National Monument-NPS	I	1 in 3	I	
PIR	Piru-2 mi SW	S	1 in 3	X	
POL	Portola	C	1 in 3	X	S
PORE1	Point Reyes National Seashore-NPS	I	1 in 3	I	
QUC	Quincy-267 North Church Street	C	1 in 3	X	
RDH	Redding-Health Dept Roof	C	1 in 6	X	
RED	Redwood City	C	1 in 3	X	



**Table 4.4-4.** (continued)

Site Code <sup>a</sup>	Site Name	Site Type <sup>a</sup>	Sampling Frequency	PM <sub>2.5</sub> Sampler <sup>b</sup>	Speciation Sampler <sup>c</sup>
RGI	Ridgecrest-Las Flores Ave	C	1 in 3	X	
ROS	Roseville-151 N Sunrise Blvd	C	1 in 6	X	S
S13 <sup>d</sup>	Sacramento-1309 T Street	C	every day	X	S
SAL	Salinas	C	1 in 3	X	S
SBC	Santa Barbara-3 W Carillo St	C	1 in 6	X	S
SCQ	Santa Cruz-2544 Soquel Dr	C	1 in 3	X	
SDP <sup>d</sup>	Sacramento-Del Paso Manor	C	some every day, some 1 in 3, some 1 in 6	X	S
SEQU1	Sequoia National Park-NPS	I	1 in 3	I	
SFA <sup>d</sup>	San Francisco-10 Arkansas St	C	1 in 6 except every day from October thru March	X	S
SGS	San Andreas-Gold Strike Road	C	1 in 6	X	
SJ4 <sup>d</sup>	San Jose-4th St	C	every day	X	S
SJT	San Jose-528 Tully Road	C	every day	X	
SLM	San Luis Obispo-Marsh St	C	1 in 6	X	
SOH <sup>d</sup>	Stockton-Hazelton St	C	1 in 3	X	S
SOLA1	South Lake Tahoe-TRPA	I	1 in 3	I	
SQV	Squaw Valley-New site	C	1 in 3		
SRF	Santa Rosa-837 Fifth St	C	1 in 3	X	
SST	Sacramento-Health Dept Stockton Blvd	C	every day	X	
STL	Santa Maria-Library (Broadway)	C	1 in 6	X	
TRU	Truckee-Fire Station	C	1 in 3	(X)	S
UKC	Ukiah-County Library	C	1 in 6	X	S
VCS <sup>d</sup>	Visalia-N Church Street	C	1 in 3	X	
VIA	Victorville-Armargosa Road	C	1 in 3	(X)	S
VJO	Vallejo-304 Tuolumne St	C	1 in 3	X	
WLN	Woodland	C	1 in 3	X	
YAS	Yuba City-Almond Street	C	1 in 6	(X)	S
YOSE1	Yosemite National Park-Turtleback Dome	I	1 in 3	I	
YOY	Yosemite National Park-Yosemite Village	C	1 in 3		

<sup>a</sup> C = core SLAMS. S = non-core SLAMS. P = special purpose. I = IMPROVE.

<sup>b</sup> X = PM<sub>2.5</sub> FRM monitor. (X) = collocated PM<sub>2.5</sub> FRMs. I = IMPROVE sampler.

<sup>c</sup> S = speciation sampler.

<sup>d</sup> One of 12 sites that are collocated with CRPAQS PM<sub>2.5</sub> aerosol measurements.

<sup>e</sup> Seasonal operating period.

The technique allows for the estimation of pollutant contributions in a three-dimensional space based on CMB source contribution estimates calculated for each site. The correlation of various PM source contribution estimates can be modeled by this technique. The input to kriging is a model fitted to the experimental variograms calculated from source contribution estimates at each site. This technique can be applied to both two-dimensional (site coordinates) and three-dimensional (site coordinates and time period) data sets so that temporal and spatial variations can be simultaneously considered. Spatio-temporal source contribution estimate data can be applied to construct pollutant maps for key air quality variables for each day or part of the day. This analysis, which is performed with *Ecological Spatial Statistical Evaluation* software (Ecosse North America, Columbus, OH), will demonstrate that the technique can be used to obtain an adequate explanation of spatial scales of influence in the San Joaquin Valley at a given time, and also variations with time. This information can be applied to:

- Define optimal sampling strategies;
- Construct variogram maps to best show the distribution of source contribution estimates; and
- Identify domains (regions) exceeding critical thresholds and standards by using non-linear kriging techniques.

Table 4.4-4 summarizes PM<sub>2.5</sub> mass and chemical measurements from the central California compliance (backbone) network. Eight of the nine of the proposed sites (Visalia being the exception) are equipped with speciation monitors. If chemical speciation data are available, CMB modeling with annual averages, seasonal averages, and selected episode days will be performed as a test case to verify the spatial scales of representation of these sites. If chemical speciation data become available at a later time, the same approach proposed here can be used by other analysts to further confirm the findings of this task. Changes in spatial contour plots with and without backbone site contribution estimates will be examined to further confirm the spatial scales of influence of these long-term monitoring sites.